Anaerobic power and capacity in amateur boxers

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Anaerobic Power and Capacity in Amateur Boxers

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by

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ABSTRACT

There were two purposes to this study. Firstly, a test was devised to measure the anaerobic power output of arm punching. Secondly, the Wingate anaerobic arm cranking test was used to assess the relationship between the maximal anaerobic power and capacity produced using this test, and the anaerobic power output produced using the innovative arm punching test. The arm punching test and the Wingate test were the independent variables. The anaerobic power output, maximal anaerobic power and capacity were the dependent variables. The testing sample consisted of a group of amateur boxers ($n = 5$). A non-significant ($p<.05$) correlation coefficient of $r = 0.55$ was found between the anaerobic power output using the arm punching test and the maximal anaerobic power using the Wingate test.

TABLE OF CONTENTS

Page

Appendices

LIST OF TABLES

LIST OF FIGURES

Chapter 1

INTRODUCTION

Purpose of the Study

The purpose of the study was twofold: (a) to devise a valid and reliable device to measure the anaerobic power output produced in arm punching, and (b) to assess the relationship between the anaerobic power output produced in arm punching and the maximal anaerobic power and capacity produced in arm cranking.

Significance of the Study

Within the field of human sports performance the anaerobic power output is an important physiological component. The levels of power which a sports performer can generate and sustain are often responsible for the success or failure of a task. With respect to amateur boxing, the ability to deliver powerful punches consistently throughout three, 3 minute rounds, should give the boxer more control of the bout (J. K. Hickey, personal communication, April 1984). It may even increase the possibility of a knockout (K.O.) or technical knockout (T.K.O.) to end the bout earlier. As such, this anaerobic energy source has often proved to be a significant factor (James, 1972), even though it is probably not the predominant energy system used.

Nevertheless, the evaluation of anaerobic power, and to a certain extent, other physiological components of boxing performance, have been based on a very traditional approach with much subjective opinion (J. K. Hickey, personal communication, April 1984). Consequently, the objective evaluation of boxing performance has been limited over the years.

However, there has been a gradual introduction of a more scientific and innovative approach to sports performance. This contemporary approach has made it possible to evaluate empirically, not only boxing performance, but also the physiological components of other sports performance. This is most noticeably seen in the laboratory measurement of aerobic metabolism in which numerous researchers have conducted tests to determine aerobic parameters such as maximum oxygen uptake ($\dot{V}O_2max$), carbon dioxide production ($\dot{V}CO_2$), and respiratory quotient (R.Q.). This information has been of vital importance to boxers and endurance athletes alike, especially in evaluating individual potential and in the restructuring of personal training programmes.

Conversely, the empirical evaluation of anaerobic metabolism has been limited. Various physiochemical tests are available to evaluate anaerobic functioning, but some authorities argue that these tests are not practical in that they necessitate invasive techniques and are costly (Grodjinovsky, Inbar, Dotan & Bar-Or, 1980). Other researchers (Jacobs et al., 1982) state that there is a lack of consensus concerning the tests which measure the anaerobic energy systems. Whatever the reasons, no universally used and accepted test has been established to evaluate anaerobic sports performance.

Consequently, several performance and mechanical tests of power have evolved. These are simple, non-invasive in nature, and indirectly estimate specific parameters (Grodjinovsky, Inbar, Dotan & Bar-Or, 1980). However, of the available tests, only a few provide a specific anaerobic evaluation of the sports action. Thus, the limited applicability of these tests reduces their potential for widespread sports evaluation and performance prediction. No test yet has provided a specific evaluation of the anaerobic power output of amateur boxers.

A few studies have utilized mechanical tests of power in the laboratory to assess the punching action (Tuinzing & Fichera, 1975; Joch, Krause & Fritsche, 1981; Atha, Yeadon, Sandover & Parsons, 1984). However, these studies have concentrated on measuring such variables as initial and final velocity, contact time, and impact force in one single or several separate explosive punches. There is still no test which could be used to measure an amateur boxer's anaerobic power output in several consecutive punches. Similarly, no non-punching mechanical test of power has been used on amateur boxers to estimate their anaerobic power and capacity. As such, the possibility of providing an expedient estimate of an amateur boxer's anaerobic power and capacity has not yet been investigated. This information could be extremely useful in determining their "anaerobic profiles".

Thus, the combined specific aims of this study were:

1. To provide a valid and reliable device which would measure the anaerobic power output produced in 15 seconds of alternate straight right and left punching.
2. To assess the relationship between this arm punching test and the valid and accepted Wingate anaerobic arm cranking test.

Delimitations

1. This study was delimited to (i) five amateur boxers from the Sharlston Amateur Boxing Club of Leeds and (ii) a punching test duration of 15 seconds.
2. The independent variables were arm punching on the specific measuring device and arm cranking on the Wingate anaerobic arm cranking test.
3. The dependent variables were anaerobic power output, maximal anaerobic power, and maximal anaerobic capacity.

Limitations

1. The subjects followed test instructions.
2. The subjects exerted maximum effort on all tests.

Definitions

Maximal anaerobic power in arm-cranking was defined as the highest power output in any 5-second period on the bicycle ergometer. This was expressed in watts and was calculated by the following formula:

Maximal anaerobic power

$$= \frac{\text{Flywheel displacement x resistance x revolutions x time (12)}}{6.12}$$

Maximal anaerobic capacity in arm cranking was defined as the total power output in the 30-second test period on the bicycle ergometer. This was expressed in watts and was calculated by the following formula:

Maximal anaerobic capacity

$$= \frac{\text{Flywheel displacement x resistance x revolutions x time (2)}}{6.12}$$

Anaerobic power output in arm punching was defined as the average power output per punch. This was expressed in watts and was calculated by the following formula:

$$\text{Anaerobic power output} = \frac{1/2\ kx^2}{t}$$

where: k = spring constant (Newton Metres)

x = maximum distance punched (cms)

t = time of the punch (seconds)

Chapter 2

REVIEW OF LITERATURE

Anaerobic Power and Capacity

The quantification and subsequent evaluation of anaerobic functioning has progressed along three lines of research. According to Evans and Quinney (1981), it has been quantified by (a) physiochemical tests, (b) performance oriented tests, and (c) mechanical tests of power.

Within the scope of physiochemical tests, several means have traditionally been used to determine anaerobic functioning. Graham and Andrew (1973) measured the oxygen debt following exhaustive exercise, while Hermansen (1971), and Margaria, Cerretelli and Mangili (1964), studied post-exercise blood lactate levels. Other researchers have analysed biopsied muscle tissue taken during (Bergstrom, Harris, Hultman & Nordesjo, 1971), and following (Gollnick & Hermansen, 1973; Gollnick & King, 1969) heavy work. As such, these tests have provided an in vivo quantification of anaerobic functioning (Thomson & Garvie, 1981).

However, as a result of using these tests, several problems have been incurred. Such problems include the lack of consensus regarding anaerobic measurements (Jacobs et al., 1982), the relative complexity and unclear validity of tests (Inbar & Bar-Or, 1979), the questionable accuracy of certain laboratory measurements (Cunningham & Faulkner, 1969; Graham & Andrew, 1973), the need for well trained staff (Bar-Or & Inbar, 1978) and the impracticability of certain tests (Bar-Or & Inbar, 1978).

As a result of these problems, over the last 25 years, an effort has been directed towards the development of anaerobic performance tests and mechanical tests of power. Margaria, Aghemo and Rovelli in 1966, were perhaps the innovative pioneers in the field of anaerobic performance tests, devising a stair climb test which accurately reflected the anaerobic power of the legs. This stair climb test, which was later modified by Kalamen in 1968, was the forerunner for many subsequent performance tests such as the anaerobic capacity treadmill tests of Cunningham and Faulkner (1969), Green and Houston (1975), Fox (1975), Sawka, Tahamont, Fitzgerald, Miles and Knowlton (1980), Thomson and Garvie (1981) and the track tests of Shaver (1975) and Thomson (1981).

During the development of these anaerobic performance tests, mechanical tests of power on the bicycle ergometer were also being devised and reported. Borg (1962) was the first to introduce a bicycle ergometer test of anaerobic capacity in which mechanical power output alone was measured. For various reasons, this mode of measurement was not accepted widely. Consequently, it was not until 1972 that Cumming reintroduced anaerobic testing on the bicycle ergometer. In his study on boys aged 12 to 17 years, Cumming calculated anaerobic capacity by counting the number of pedal revolutions in 30 seconds (where one pedal revolution caused a 6-metre advance of the flywheel), against a resistance of 4.5 kiloponds (k.p.) using a Monark bicycle ergometer. This test was modified by a number of researchers and several variations evolved. Chaloupecky (1972) devised a test which consisted of 85 pedal revolutions against a resistance of 4 k.p. De Bruyn-Prevost (1974) devised a supramaximal test of 30 to 60 seconds duration. Szögy and Cherebetiu (1974) produced a test which consisted basically in pedalling as many revolutions as possible in 60 seconds, while Katch and Weltman (1979) devised a test consisting of 120 seconds duration, in which the subject pedalled at a resistance of 24 kilopond metres per second.

The most prominent anaerobic bicycle ergometer test developed was the Wingate anaerobic test which was formally described in Hebrew by Bar-Or in 1977 (Bar-Or, personal communication, July 1985). The unique feature of this test was that the bicycle resistance was adjusted to bodyweight. In addition, power output could be computed every 5 or 6 seconds for a maximum test duration of 30 seconds. This enabled a power and capacity value to be obtained. Upper limbs, as well as lower limbs, could be evaluated in this manner, but with reduced resistance.

This anaerobic arm or leg test has been found to be reliable with a test-retest of r = 0.95 to 0.97 in various groups of children, adolescents, and young adults (Bar-Or, Dotan & Inbar, 1977). A number of observations have also been made to validate the Wingate anaerobic test against accepted criteria of anaerobic power and capacity. The leg anaerobic power has been correlated with the power output of the Margaria stair climb test and was found to be r = 0.79 (Ayalon, Inbar & Bar-Or, 1974). Similarly, Bar-Or and Inbar (1978) reported the respective leg anaerobic power and capacity correlations with 40-metre and 300-metre running times of r = 0.84 and r = 0.83 in young boys. In young boys and girls of varying swimming ability, Inbar and Bar-Or (1977) found arm anaerobic capacity correlations with 25-metre sprint swimming of r = -0.87 to r = -0.92. Even maximal oxygen debt has been correlated with leg anaerobic capacity and has been reported as r = 0.86 (Bar-Or, Dotan & Inbar, 1977). In addition, the Wingate arm and leg anaerobic tests have been shown to be sensitive to training effects in young adults (Inbar & Bar-Or, 1979) and adolescents (Armstrong & Ellard, 1983).

It is for the above reasons of reliability, validity, sensitivity, and overall simplicity, that the Wingate anaerobic test has been accepted widely, and utilized extensively in research on the maximal anaerobic power and capacity of the arms and legs.

The Measurement of a Punch

Without specific punch measuring devices an empirical evaluation of the fast and explosive punching action is difficult. Through the use of such devices, the researcher is able to detail an empirical kinetic or kinematic evaluation of the punch. However, of the available research, only a few comprehensive studies have been reported. No study has attempted to analyse the anaerobic power output of punching performance in amateur boxers.

Tuinzing and Fichera (1975) measured several biomechanical parameters of 30 black belt karateka and 10 relatively experienced amateur boxers. These researchers used a padded board hung on a hollow aluminium pendulum (the target), a Hewlett-Packard storage oscilloscope, two photoelectric cells, a Heath IU-8 digital timer and an accelerometer. Hand velocity was calculated by mounting two photoelectric cells, connected to an IU-8 digital timer, parallel to the target. The accelerometer was attached to the back of the target, and had an output which appeared on the oscilloscope. This allowed the direct calculation of contact time, peak acceleration of the mass, time to reach peak acceleration, and the derived calculation of impact force. From this research, Tuinzing and Fichera published data for hand velocity, contact time and impact force. The respective values for boxers and karateka were 40.7 and 33.2 feet per second, 10.3 and 9.2 milliseconds, and 168.8 and 154.5 pounds (lbs).

Joch, Krause and Fritsche (1981) analysed over 600 characteristics of 70 boxers. The major characteristics studied were ground reaction forces, impact forces, elbow angles, and reaction time. These characteristics were measured respectively by a Kistler force platform, a punch dynamometer (Patent: P2717104, GL01L 5/02, 78, GFR), an electronic goniometer (Neukomm, 1975), and an electronic reactionmeter (Witt, Imbi, Berlin). For this study, the researchers used three different groups of boxers. Group I consisted of 'A' level German Amateur Boxing Association and Federal League, group II consisted of 'B' level German Amateur Boxing Association and Federal League, and group III consisted of subjects who had no boxing ring experience, but who had completed basic boxing training. The pertinent finding of this study was that the punching force (impact force) and the punching speed (time to strike the target and return to pre-strike position) of the boxer depended on his performance class. Group I boxers were significantly different from the other two lower performance groups. The respective recorded force and speed values were 3453 Newtons and 446 milliseconds for group I, 3023 Newtons and 574 milliseconds for group II, and 2932 Newtons and 633 milliseconds for group III.

Atha, Yeadon, Sandover and Parsons (1984) produced an extensive study on a world ranked professional heavyweight boxer, with the biomechanical properties of the punch being measured by several complimentary techniques. The subject punched a padded target plate of an instrumented mass suspended as a ballistic pendulum. The punches were filmed at 64 Hertz (Hz) with a Bolex 16 mm cine-camera, and at 400 and 1500 Hz with a Hycam rotating prism camera. The motion of the fist and of the target mass were also continuously monitored both by means of a Coda-3 three dimensional coordinate analyser and by accelerometers attached to the fist and target. A force transducer, sandwiched between the target plate and the rest of the mass, recorded the time history of the impact force.

Using these techniques, the researchers found that the most powerful punch to land squarely on target and accelerate it in the film plane was the third punch of seven separate punches. In this punch, the fist travelled 0.49 metres, from the moment the elbow moved to the instant of peak contact force, accelerating in 100 milliseconds, from a slow 1.0 metre per second preparatory velocity, to a constant velocity of 8.9 metres per second. The peak impact force was achieved in 14 milliseconds from the first detectable force record. The magnitude of the criterion peak force from the corrected force transducer records was 4130 Newtons. Impact forces of 3600 Newtons and 4600 Newtons were recorded respectively from film data and accelerometer records.

Other researchers (Melton, 1981; Volodin & Plakhtienko 1978; Mizerski & Radziszewska, 1978; Bagreev & Trahimovitch, 1981; Dainty, Egan & Gallup, 1982; D. Gaskill, personal communication, May 1984; Therrien & Dessureault, 1982; Roy, Bernier-Cardou, Cardou & Plamondon, 1984) have also conducted studies within the field of punch measurement using various punch recording devices. Such studies though, like those already described, have not attempted to analyze a boxer's anaerobic power output in several consecutive punches. This is surprising since the levels of anaerobic power which can be generated and sustained are significant, if not critical factors in amateur boxing performance. The reasons for this lack of empirical investigation into the anaerobic power output of amateur boxers could be (a) that it is not considered to be a significant part of amateur boxing performance due to the probable predominant use of the aerobic energy system, (b) the lack of a specific measuring device, and (c) the lack of a measuring protocol.

Whatever the reasons for not evaluating the anaerobic power output of amateur boxers, it is the author's opinion that there is a clear need to at least attempt to analyse this physiological component. With additional anaerobic power and capacity information being derived from the Wingate anaerobic arm cranking test, a fuller understanding of this anaerobic energy source, as it relates to amateur boxing, may be ascertained. Thus, the major aim of this study was to utilize and develop testing equipment that is specific to anaerobic boxing performance. As Bouchard, Taylor and Dulac (1982) stated:

> ...laboratory tests of maximal anaerobic power and capacity are of greatest relevance to the athlete when they simulate his actual mode of exercise and involve the specific muscle groups which he uses in his sport. For many sports, this means that commercially available ergometry equipment will have to be modified, while for others, specific equipment will have to be constructed. (p. 63)

Chapter 3

METHODS AND PROCEDURES

Re-statement of the Problem

The purpose of this study was twofold: (a) to devise a valid and reliable device to measure the anaerobic power output produced in arm punching, and (b) to assess the relationship between the anaerobic power output produced in arm punching and the maximal anaerobic power and capacity produced in arm cranking.

Subjects

Table 1

Physical Characteristics of Subjects

Subjects (n=5)	Age (yrs)	Weight (kg)
1	22	89
2	21	70
3	22	75
4	25	80
5	23	92
$\bar{x}$	22.6	81.2
S.D.	1.52	9.26

There were 5 subjects participating in this study. All the subjects were selected from the Sharlston Amateur Boxing Club. All testing was performed at Leeds Polytechnic.

Apparatus

To measure the anaerobic power output produced in arm punching and the maximal anaerobic power and capacity produced in arm cranking, two specific tests were used: (a) an arm punching test, and (b) the Wingate anaerobic arm cranking test.

(a) Arm Punching Test. For this test a specific device was constructed (Appendix A; figure 1). When the striking plate was punched (Appendix A; figure 2), the sliding column moved over the static column and the maximum force (f) was recorded by a readout device. Concomitantly, the extended measuring needle was forced along the adjacent measuring scale and the maximum distance (X), and the time to reach that maximum distance (t), was recorded by high speed photography (Super 8 mm). When the punch had been completed the striking plate returned to its pre-strike position by use of a static collar and the force readout device was re-set to zero. Thus, the variables of F, X, and t could be used to determine the anaerobic power output per punch.

In the preliminary trials, this method of power calculation posed a problem which was not anticipated in the initial design and construction of the arm punching device. The problem concerned the force readout device.

On average, up to 3 punches (forces) could be recorded reliably, but with more consecutive punches, the device was slow to re-set to zero and so some punches were not recorded.

Subsequently, another equation was used to calculate the anaerobic power output produced during arm punching. This method used the equation:

$$\text{Anaerobic Power Output} = \frac{1/2\ k\ x^2}{t}$$

where: k = spring constant

x = maximum distance punched

t = time of the punch

Instead of finding a force value for each punch from the force readout device, it would be possible to calculate the spring constant (-K) ie, the degree of spring displacement on contraction as loads or forces were imposed upon it. This would constitute a calibration curve (see Calibration Procedure page 18). Thus, for each load or force which was placed on the striking plate, the spring would contract a certain distance (X).

Hence $F = -KX$

Where: $= -K$ = spring constant

X = displacement

(b) Wingate Anaerobic Arm Cranking Test. This test used a Monark bicycle ergometer which was elevated on a platform above the subject and had the pedals replaced by hand grips (Appendix B). Maximal anaerobic power and capacity was calculated by using the distance the flywheel travelled per revolution, the resistance setting and the revolutions per 30 seconds. The distance the flywheel travelled was a constant value. The resistance setting was pre-determined based on the subject's bodyweight, and the number of arm crank revolutions was recorded by interfacing a microcomputer to the bicycle ergometer.

Pilot Study

A pilot study was conducted on each of the two tests.

(i) Arm Punching Test Pilot Study. This study resolved problems associated with using and developing the anaerobic arm punching test.

Firstly, the maximum distance of each punch had to be measured. A slow frame rate would not give a high enough resolution of the scale marker on the scale and so only a blurred image would be produced. A frame rate which was too high would yield a clear differentiation of the scale marker, but would cut the total filming time down to less than the 15 seconds required for the test. By filming at various speeds, it was found that a frame-rate of 200 frames per second gave a high enough resolution to enable minimum measurement to be 0.25 cm. This frame-rate also made it possible to film for 15 seconds (test duration).

Secondly, by observing several trials, the standardization of the punching position and action could be established.

(ii) Wingate Arm Cranking Test Pilot Study. A pilot study was also needed on this test in order to establish optimal resistances for the subjects. In previous experiments, researchers have used resistances ranging from .033 to .050 kp/kg bodyweight (Ayalon, Inbar & Bar-Or, 1974; Bar-Or & Inbar, 1978; Inbar & Bar-Or, 1977). In these studies the subjects have ranged from boys to healthy males. In the undertaken study though, the subjects were amateur boxers who used their arms extensively in their sport.

Bar-Or (personal communication, Jan. 1986) suggested extrapolating the resistances used in his extensive studies on pre-adolescent and adolescent boys, to accommodate heavier subjects. If these subjects were then from an athletic population, and additional 10-15% of that resistance could be used as the optimal resistance.

However, this method of ascertaining optimal resistance for athletic populations has not yet been fully established. Therefore, a pilot study was undertaken to find out the optimal resistances for the amateur boxers. This study established that for this particular group, an optimal resistance was .060 kp/kg bodyweight.

Calibration Procedure

Two forms of calibration were conducted on the punching device in order to determine (a) the calibration curve, and (b) the ability of the device to yield correct force values at different points on the striking plate.

To determine (a), known weights (pre-weighed on an Ohaus Solution Beam Balance) were placed on the striking plate. Each incremental load compressed the springs on the underside of the striking plate. The amount of compression or displacement was measured by a sliding microscope (Griffin & George Ltd., London). By plotting the displacement of the spring from a zero load to a maximum load, a line of best-fit was computed. This was the calibration curve and produced k, the spring constant (Appendix C from the graph, k = 9959 N/M).

To determine (b), the punching device was placed in a Tinius-Olsen FM1819 Universal Testing Machine (Philadelphia, U.S.A.) with a calibrated load cell inserted at the point of application of force. Loads of up to 190 lbs were applied at five separate points (Appendix D).

At each load, both the inserted load cell readout and the punching device readout was recorded, and the difference noted as an error (Appendix E). The percentage error was less than 2%.

For the calibration of the Monark bicycle ergometer, pre-weighed calibration weights were suspended at incremental loads on the flywheel and the ergometer was set at the corresponding resistances.

Reliability Procedure

Reliability took 4 days to complete. The 5 subjects were randomly assigned to group A or B and tested in the order shown below. Each testing session occurred at the same time of day.

	Group A (n=3)	Group B (n=2)
Day 1	Arm punching test	Wingate test
Day 2	Arm punching test	Wingate test
Day 3	Wingate test	Arm punching test
Day 4	Wingate test	Arm punching test

Prior habituation to the specific testing was necessary in order to ensure that there were no task learning effects.

Testing Procedures

All testing took 2 days to complete. The subjects were randomly assigned to group A or B and were tested in the order shown below. Each testing session occurred at the same time of day.

	Group A (n=3)	Group B (n=2)
Day 1	Arm punching test	Wingate test
Day 2	Wingate test	Arm punching test

All subjects signed an informed consent form and were told to report for testing 2 hours post-absorptive and not to perform any strenuous activity the day before the testing.

Arm Punching Test Protocol

1. On reporting to the laboratory, the 5 subjects were randomly assigned to group A or B.
2. The subjects in group A were given a list of test instructions (Appendix F) and were also advised to conduct their own warm-up. To facilitate this, a

hanging punching bag was placed in a nearby room. Subjects were also informed that they were allowed 10 warm-up punches on the apparatus immediately before actual testing.

3. When ready, the first subject returned to the laboratory and put on a pair of standard 8 oz boxing gloves. The subject then stood square-on to the target (striking plate) and fully extended his right arm so that his gloved fist lightly touched the target. This constituted the exact punching distance which was used in the test.
4. After this punching distance had been found, the subject's feet were placed 12 inches apart with neither foot being behind or in front of the other. A marked square was then placed around the feet. The subject was reminded that one or both feet must not leave the floor or go out of the marked square.
5. The subject was then allowed 10 warm-up punches and was reminded that each fist must return to chin level next to the shoulder after each punch.
6. The loaded high speed camera was placed facing the punching scale (at 90° to the scale).
7. On the command "go", the subject began punching (right first). At the same time, the high speed camera was switched on.

8. The test duration (15 seconds) was not told to the subject to avoid subject pacing. However, verbal encouragement was given throughout the test.
9. When 15 seconds of punching had been completed, the subject was told to stop punching and to slowly warm-down. At the same time the camera was switched off. The film was unloaded and a new film was loaded into the camera for the next subject.
10. The above protocol was carried out for all subjects.

Wingate Test Protocol

1. The subjects in group B were given a list of test instructions (Appendix G).
2. The first subject was weighed (Health-o-meter weighing scale) and his weight was used to determine his arm crank resistance.
3. The subject was then seated at a comfortable distance from the bicycle ergometer. The arms were extended and the hands were placed on the hand grips.
4. The subject was told to remain in the seat at all times during the test.
5. The subject then performed a 2 minute warm-up of arm cranking.
6. After the 2 minute warm-up period and on the command "go", the subject arm cranked all-out. Concomitantly, the ergometer resistance was set.
7. Once the resistance had been set, the microcomputer was

started and this signified the timed start of the test.

8. The test duration (30 seconds) was not told to the subject to avoid subject pacing. However, verbal encouragement was given throughout the test.

9. When 30 seconds of arm-cranking had been completed, the subject was told to stop all-out arm-cranking and to slowly warm-down. The number of revolutions was then recorded by the microcomputer.

10. The above protocol was carried out for all subjects.

Analysis of Data

The reliability study used a single classification analysis of variance ANOVA on the arm punching test and the Wingate test. This analysis was later confirmed by applying a paired - samples t - test for significant difference testing between means of the data.

In certain situations the application of the ANOVA was inapplicable due to the level of data presented and limited sample size. Therefore, the paired - samples t - test which can be applied to particularly small samples with normal distributions and homogeneity of variance was used as an alternative reliability test.

The computed final testing data from both tests were analyzed using the Pearson Product Moment Correlation Coefficient. The level of significance was set at $p<.05$.

Chapter 4

RESULTS

Reliability Data

Generally the two tests were shown to be reliable with good agreement between testing days (see tables 2 and 3 below).

WINGATE

Table 2 Single Classification Analysis of Variance showing F ratio and F probability together with paired samples T testing for examination of data reliability.

DAY 1 AND DAY 2 WINGATE

VARIABLES	F. RATIO	F. PROB	T. VALUE	2 TAIL PROB	SIGNIFICANCE NON. SIG.
5	5.40	0.1563	0.53	0.621	NON. SIG.
10	0.575	0.6349	0.53	0.621	NON. SIG.
15	N/A	N/A	0.35	0.757	NON. SIG.
25	N/A	N/A	0.16	0.883	NON. SIG.
30	N/A	N/A	0.45	0.677	NON. SIG.
TOT	N/A	N/A	0.40	0.708	NON. SIG.

Table 3

ANOVA Value for test of significance together with t-test values for confirmation of results for the Arm Punching test.

DAY 1 AND DAY 2 ARM PUNCHING

VARIABLES	F. RATIO	F. PROB	T. VALUE	2 TAIL PROB	SIGNIFICANCE NON. SIG.
5 SECOND	N/A	N/A	1.48	0.212	NON. SIG.
10 SECOND	N/A	N/A	-0.89	0.425	NON. SIG.
15 SECOND	N/A	N/A	-0.75	0.495	NON. SIG.
TOT.	N/A	N/A	0.78	0.478	NON. SIG.

Final Data

The highest group mean maximum anaerobic power value on the Wingate test occurred at 10 seconds (x = 551.06 watts - S.D. = 106.76) (Tables 4 and 5). At this time period, the highest value (711.76 watts) was obtained from subject 1 (92 kg) and the lowest value (423.53 watts) was obtained from subject 3 (75 kg). The lowest group mean anaerobic power value occurred, as one might expect, at 30 seconds (x = 272.23 watts).

The Wingate test group mean maximum anaerobic capacity was 406.04 watts (S.D. = 51.22). The highest value (474.51 watts) was obtained by subject 5 (92 kg) and the lowest value (362.35 watts) was obtained by subject 2 (70 kg) (Tables 4 and 5).

The highest group mean maximum anaerobic power "output" value on the arm punching test occurred at 5 seconds (x = 273.63 watts - S.D. = 45.06) (Tables 4 and 6). At this time period, the highest value (340.54 watts) was obtained from subject 1 (89 kg) and the lowest value (231.39 watts) was obtained from subject 3 (75 kg). The lowest group mean maximum anaerobic power "output" value occurred at 15 seconds (x = 134.49 watts - S.D. = 8.67).

The punching test group mean maximum anaerobic power "output" average over 15 seconds was 224.16 watts (S.D. = 22.36). The highest value (255.86 watts) was obtained by subject 1 (89 kg) and the lowest value (198.85 watts) was obtained by subject 2 (70 kg) (Tables 4 and 6).

The correlation coefficient between the Wingate anaerobic arm cranking test and the arm punching test was r = 0.55. This was non-significant at the 0.95 level of significance and was interpreted as only a modest correlation.

Table 4
Maximum Group Mean Anaerobic Power (M.A.P.) and Capacity (M.A.C.) (Wingate Test) and Maximum Group Mean Anaerobic Power Output (M.A.P.O.) and Total Output (T.O.) (Arm Punching Test)

	Wingate Test	
M.A.P. (5 sec)	Watts Watts kg BW-1	551.06 + 106.77 6.76 + 0.80
M.A.C. (30 sec)	Watts Watts kg BW-1	406.04 + 51.22 5.00 + 0.23
	Arm Punching Test	
M.A.P.O. (5 sec)	Watts Watts kg BW-1	273.63 + 45.06 3.38 + 0.48
A.P.O. (15 sec)	Watts Watts kg BW-1	224.16 + 22.36 2.77 + 0.03

Table 5

Wingate Anaerobic Arm Cranking Test

Final Testing Data Table

Subjects	5	10	15	20	25	30	Watts) Total Capacity
1	498.82	561.18	498.82	436.12	374.12	311.76	446.86
2	444.71	494.12	395.29	296.47	296.97	247.06	362.35
3	529.41	423.53	370.59	317.65	317.65	317.65	379.41
4	508.24	564.71	338.82	282.35	282.35	225.88	367.06
5	647.06	711.76	517.65	452.94	258.82	258.82	474.51
$\bar{X}$	525.65	551.06	424.23	357.18	305.88	272.23	406.04
S.D.		83.04					51.22

Table 6

Arm Punching Test Final Testing Data Table

Subjects	5 Second Anaerobic Power Output (Watts)	10 Second Anaerobic Power Output (Watts)	15 Second Anaerobic Power Output (Watts)	Average Anaerobic Power Output (Watts)
No. 1	340.54	290.68	136.34	255.86
No. 2	250.70	212.80	133.04	198.85
No. 3	231.39	274.1	126.84	210.78
No. 4	298.56	230.46	127.86	218.96
No. 5	246.94	313.69	148.37	236.33
x	273.63	264.35	134.49	224.16
S.D.	45.06	41.92	8.67	22.36
No. of Punches	41	43	38	122

Chapter 5

DISCUSSION

Reliability

The reliability data for the ANOVA and t - test carried out on the Wingate test are presented in table 2. The results showed that no significant differences exist between the two days testing on all the test variables examined. Generally, the Wingate test was shown to be a reliable and reproducible test for anaerobic power and capacity.

The data for the arm punching test is presented in table 3. The results outlined that no significant differences exist between the results for the test on day 1 and day 2. Hence, the data was considered to be reliable and reproducible on this occasion.

All the reliability data presented in this analysis was examined for normal distribution and homogeneity of variance. The assumption of random sampling was a logical one. None of the compared data showed significantly different variance and all the values had non-significant coefficients of skewness. Hence, the data was suitable for parametric statistical analysis.

Wingate Test

In evaluating the maximum anaerobic power and capacity curve of the group (n = 5), the anaerobic power rises continually to 10 seconds, reaching a peak of 551.06 watts, and then gradually declines to a final value of 272.23 watts (figure 1). As such, this curve is characteristic of the anaerobic power and capacity produced using the Wingate test

(Kaczkowski, Montgomery, Taylor & Klissouras, 1982).

In achieving the above values, a resistance of 0.060 kp/kg bodyweight was used. This resistance was higher than in other studies (Inbar & Bar-Or, 1977; Bar-Or & Inbar, 1978; Ayalon, Inbar & Bar-Or, 1974; Armstrong & Ellard, 1983) where the resistance ranged from 0.033 kp/kg bodyweight to 0.050 kp/kg bodyweight. These studies, however used young boys, girls and healthy males. From pilot studies, a resistance of 0.060 kp/kg bodyweight proved to be a more realistic optimal resistance in this study.

Overall, the whole group produced high anaerobic power and capacity values of 551.06 watts and 406 watts respectively.

Individually, subject 5 (92 kg) produced the highest anaerobic power and capacity values of 711.76 watts and 474.51 watts respectively (Tables 4 and 5).

In other studies there has been a wide range of reported anaerobic power and capacity values. Inbar & Bar-Or (1977) using 8-12 year old boys and girls, reported mean anaerobic capacity values ranging from 102.2 watts to 232 watts. Bar-Or & Inbar (1973) found a mean anaerobic capacity value of 155 watts and a mean anaerobic power value of 122 watts using boys with a mean age of 12 years. Ayalon, Inbar and Bar-Or (1974) tested 19-21 year old untrained male subjects and reported an anaerobic capacity value of 606 watts. Armstrong and Ellard (1983) tested untrained (n = 28) and trained (n = 8) boys and found anaerobic power values of 199 watts and

332.4 watts respectively, and anaerobic capacity values of 152.9 watts and 268.6 watts respectively.

From this data, it is apparent that there are variable anaerobic power and capacity values reported in the literature. As stated, this could be a result of the lower resistance and the type of subjects used.

Arm Punching Test

The arm punching anaerobic power output curve had the highest group mean anaerobic power value occurring after 5 seconds (273.63 watts). This was marginally more than after 10 seconds (264.35 watts). A most interesting feature of the curve was the dramatic decrease in the anaerobic power output from 10 to 15 seconds (134.49 watts) (Figure 2). This may be an indication that the test proved to be very exhausting after 10 seconds. Similarly, the standard deviation for the 5 and 10 second periods was 45.01 watts and 41.92 watts respectively. However, at 15 seconds the standard deviation was only 8.67 watts (Table 6). This may indicate that the subjects tired at a very similar rate.

In explaining the above, the decrease in the number of punches from 5 seconds (41 punches) to 15 seconds (38 punches) was only 3 punches (Table 6 and Figure 3). Therefore, it may be reasonable to assume that the force of punching, and not the rate of punching was responsible for such a low 15 second value. From the initial raw data of the test (Appendix K), this meant that the punching time (t) increased slightly, while the punching force and distance 2

(1/2 kx) decreased slightly. Conversely, it could mean that the punching device is not sensitive enough in recording smaller anaerobic power outputs.

It is also interesting to note that although more punches were thrown by the 10 second period (43) as opposed to the 5 second period (41), the anaerobic power output was lower (Table 6 and Figure 3). This may indicate that there is an optimal rate of punching to achieve a maximum anaerobic power output value.

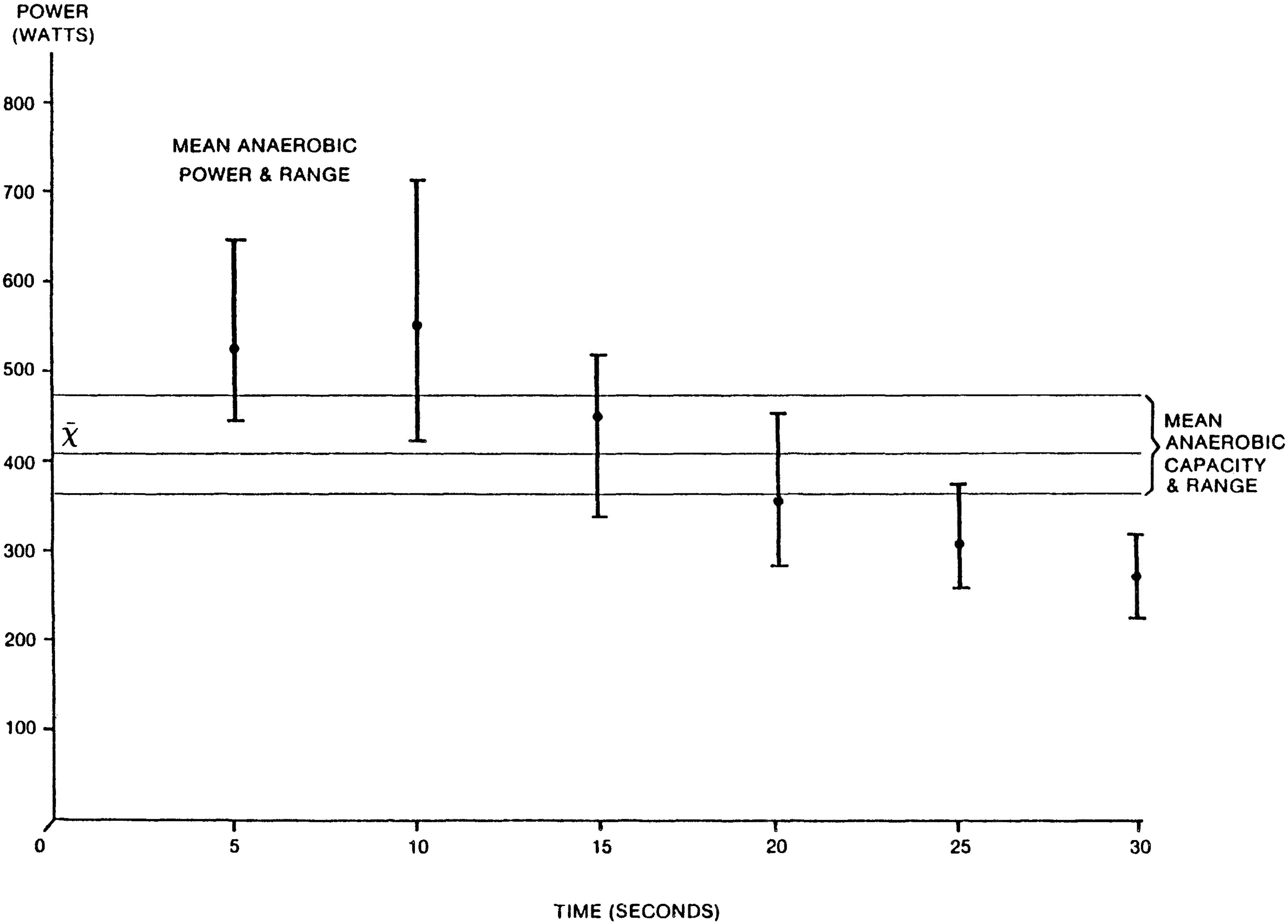
In comparing the arm punching test and the Wingate arm-cranking test, a correlation coefficient between anaerobic power outputs was $r = 0.55$. This was non-significant at the 0.95 level. However, this can be interpreted as a modest correlation value (Cohen & Holliday, 1979) and is very encouraging when considering the possible reasons why a high correlation coefficient was not found:

1. The computation of power was different for the two tests, even though both were reported in watts. The Wingate test yielded a higher absolute watt value (551.06 watts) than the arm-punching test value (273.63 watts). When computing the power output of the arm-punching test, only the measured power is used in the final watt value. This excludes the period up to striking the striking plate and following maximum impact.

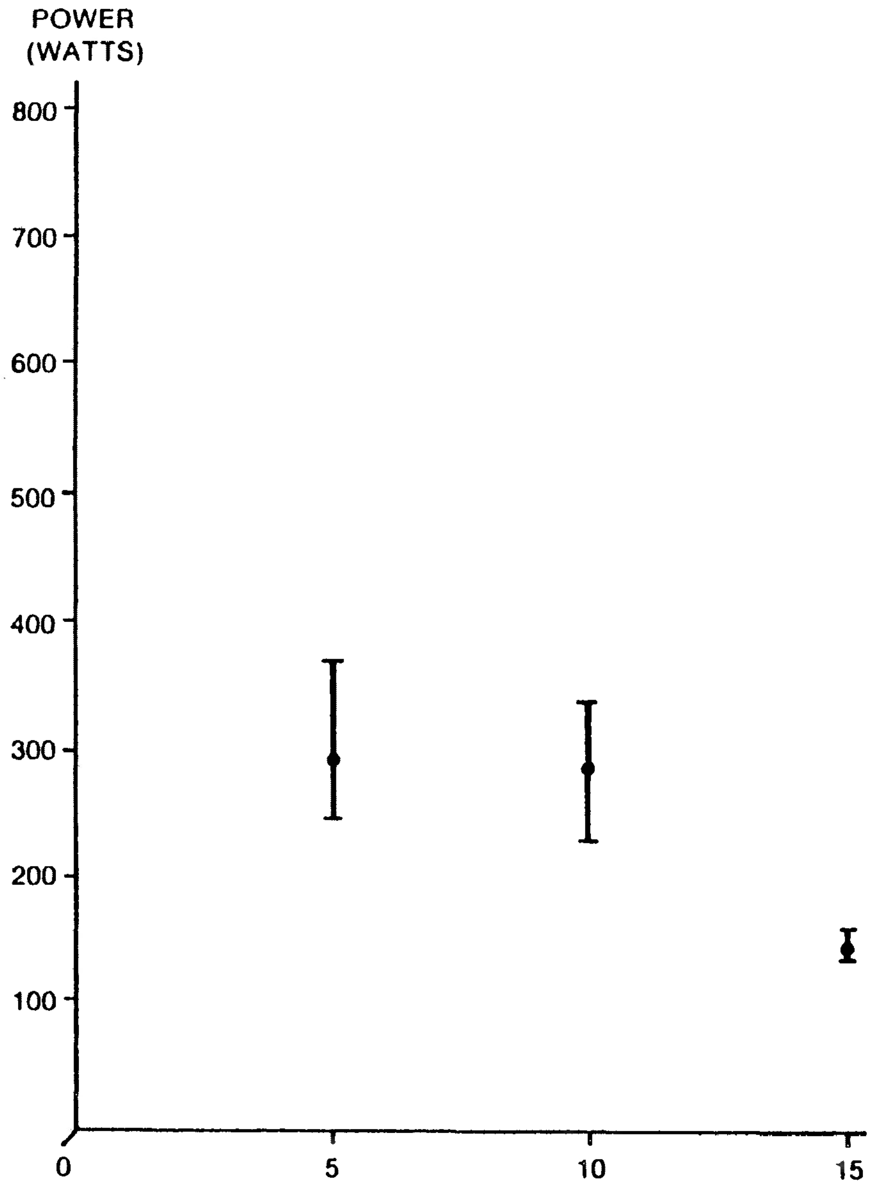
2. It may be that the unique nature of punching can only be measured accurately by a specific device. As such, to use the Wingate test as an expedient measure of anaerobic power in punching may be inappropriate.
3. However, perhaps the major reason for the lack of a significant correlation was the sample size (n = 5). Even a small variance can significantly affect group values. This point can be seen in the cross-ranking of subjects on both tests (Table 7). If subjects 1 and 5 were eliminated, there would be an almost perfect cross-ranking on both tests by subjects 2, 3 and 4. It was also interesting to note that subjects 1 and 5 were the heaviest in the group, and it may be that the heavier resistance may have affected these subjects more than the rest of the group.

Figure 1

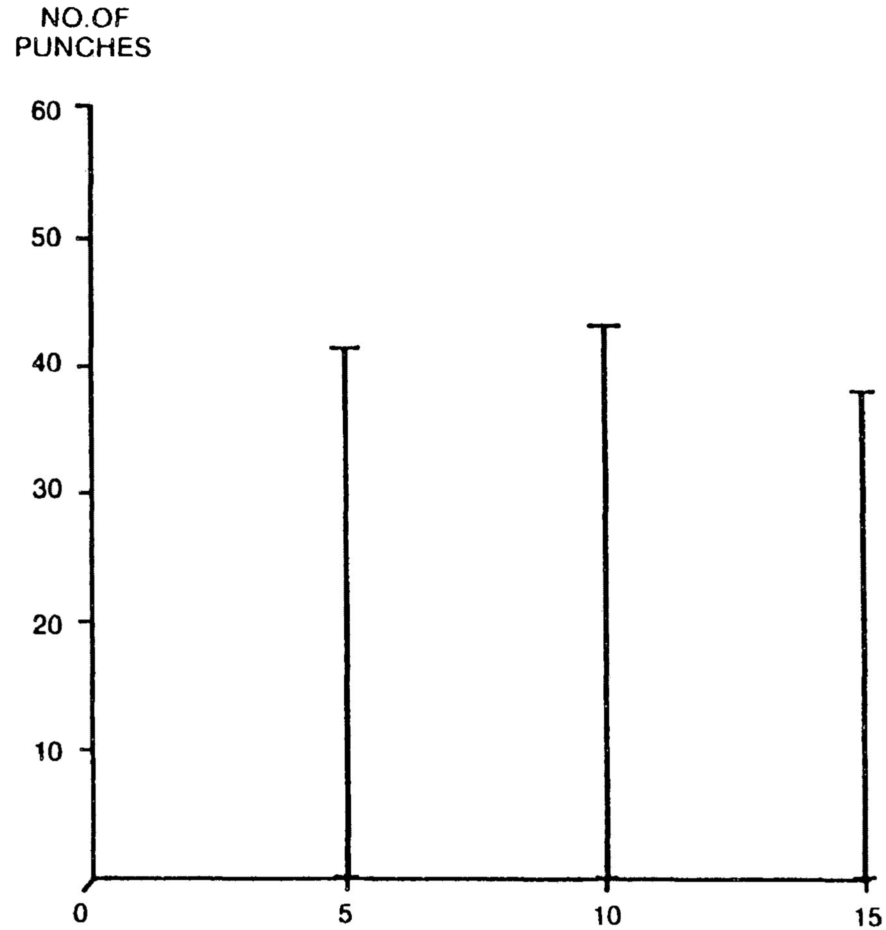
GROUP MEAN ($\bar{x}$) AND RANGE OF ANAEROBIC POWER AND CAPACITY ON THE WINGATE TEST.



GROUP MEAN ($\bar{x}$) AND RANGE OF ANAEROBIC POWER OUTPUT ON ARM PUNCHING TEST.



TOTAL GROUP PUNCHES ON ARM PUNCHING TEST.



TIME (SECONDS)

Figure 3

Table 5

Comparison of Highest Group Mean Anaerobic Power Values With Cross Ranking In Brackets

Subjects	Wingate Test	Arm Punching Test
1	561.18 (3)	(1) 340.54
2	494.12 (4)	(3) 250.70
3	423.53 (5)	(5) 231.56
4	564.77 (2)	(2) 298.56
5	711.76 (1)	(4) 246.94

Chapter 6

RECOMMENDATIONS AND CONCLUSIONS

Recommendations

There are several recommendations which should be made:

(1) The sample size should be increased. A larger sample would have been used in this study, but the cost of filming (pilot studies, reliability and actual testing) is very expensive. In addition, it is extremely time consuming analysing each individual's film data. Ideally, a form of instant feedback is needed and this would solve the above problems of sample size, cost and time.

(2) The sample characteristics should be examined. This study used subjects from various weight classes (70 kg-90 kg) primarily because of the limited availability of other subjects. It may be more advantageous to use a more homogenous group in terms of weight category. Similarly, such factors as boxing experience and age may be examined to establish trends between the arm punching test and the Wingate test.

(3) Further research is needed to establish an optimal resistance for the Wingate anaerobic arm cranking test when using athletic populations.

Conclusions

The major aim of this study was to develop and utilize testing equipment specific to anaerobic boxing performance. To this end, more information concerning the testing and evaluation of a specific, intricate punching action has been provided. The derived information, however, should only be considered as the first step in establishing an anaerobic boxing performance test.

In order to establish the punching test as an accurate measure of anaerobic power output in itself, further testing is needed with a larger and varied sample. This will enable norms to be established which may eventually determine a specific reliability level.

The particular problems associated with measuring the anaerobic power output on the punching test, and the anaerobic power and capacity on the Wingate test, have been highlighted. It is these problems which need to be further examined to determine if the anaerobic power output produced in arm punching can be predicted from the Wingate anaerobic arm cranking test. This may then provide an expedient estimate of anaerobic boxing performance.

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RM PUNCHING
EVICE

Striking Plate
Spring
Sliding Column
Sliding Column
Static Collar
Fixed Column
Scale
Force Transducer (Load Cell)
End Plate
Force Transducer Readout
Device

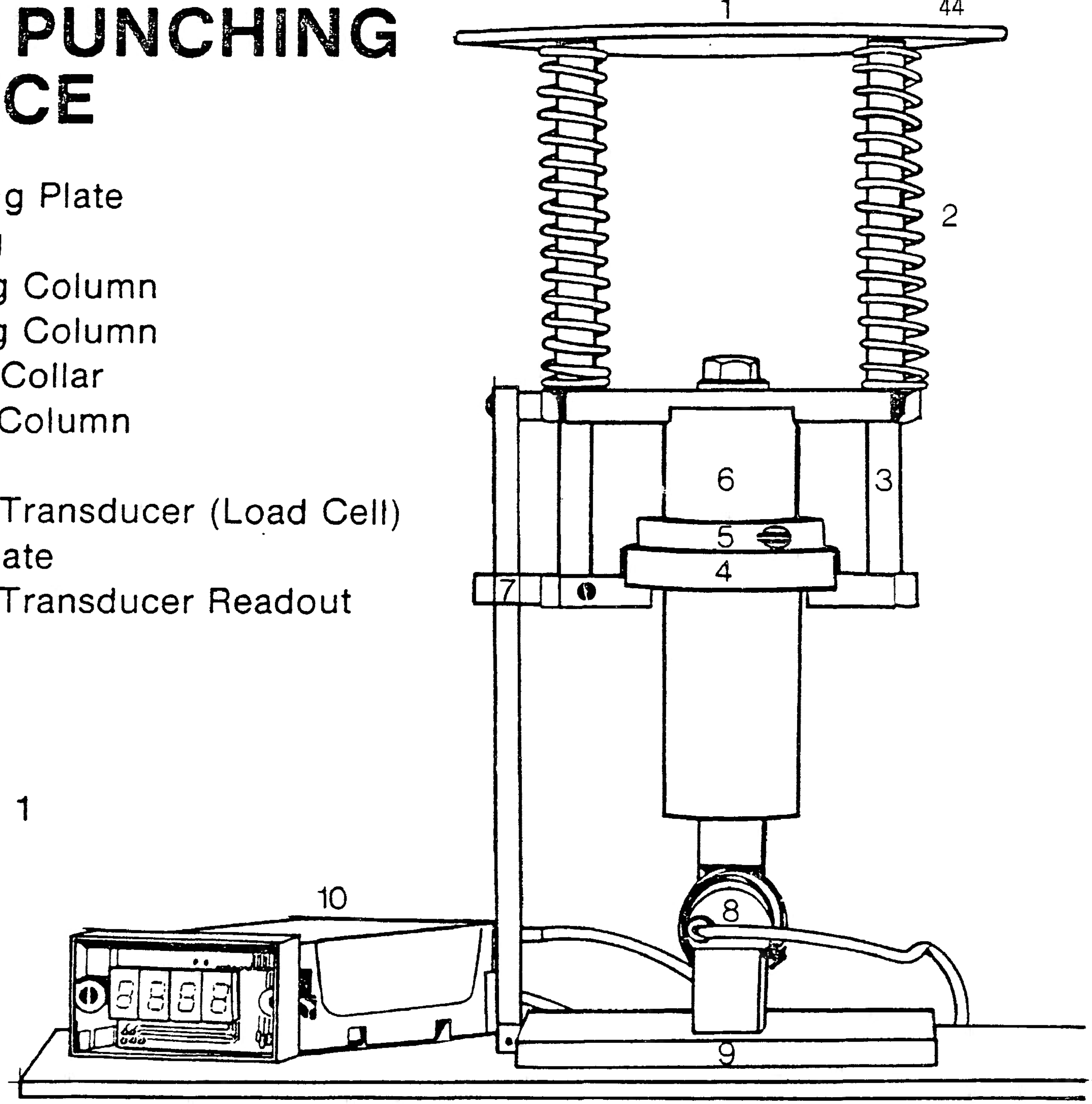
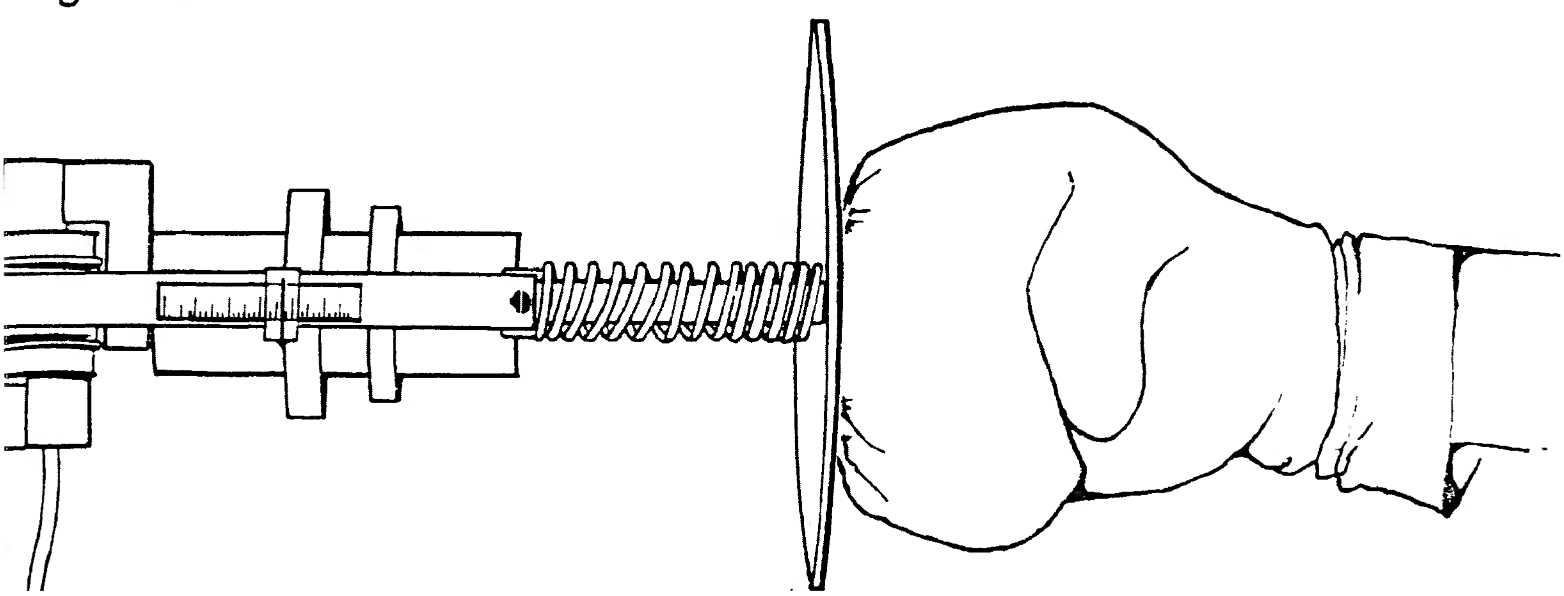


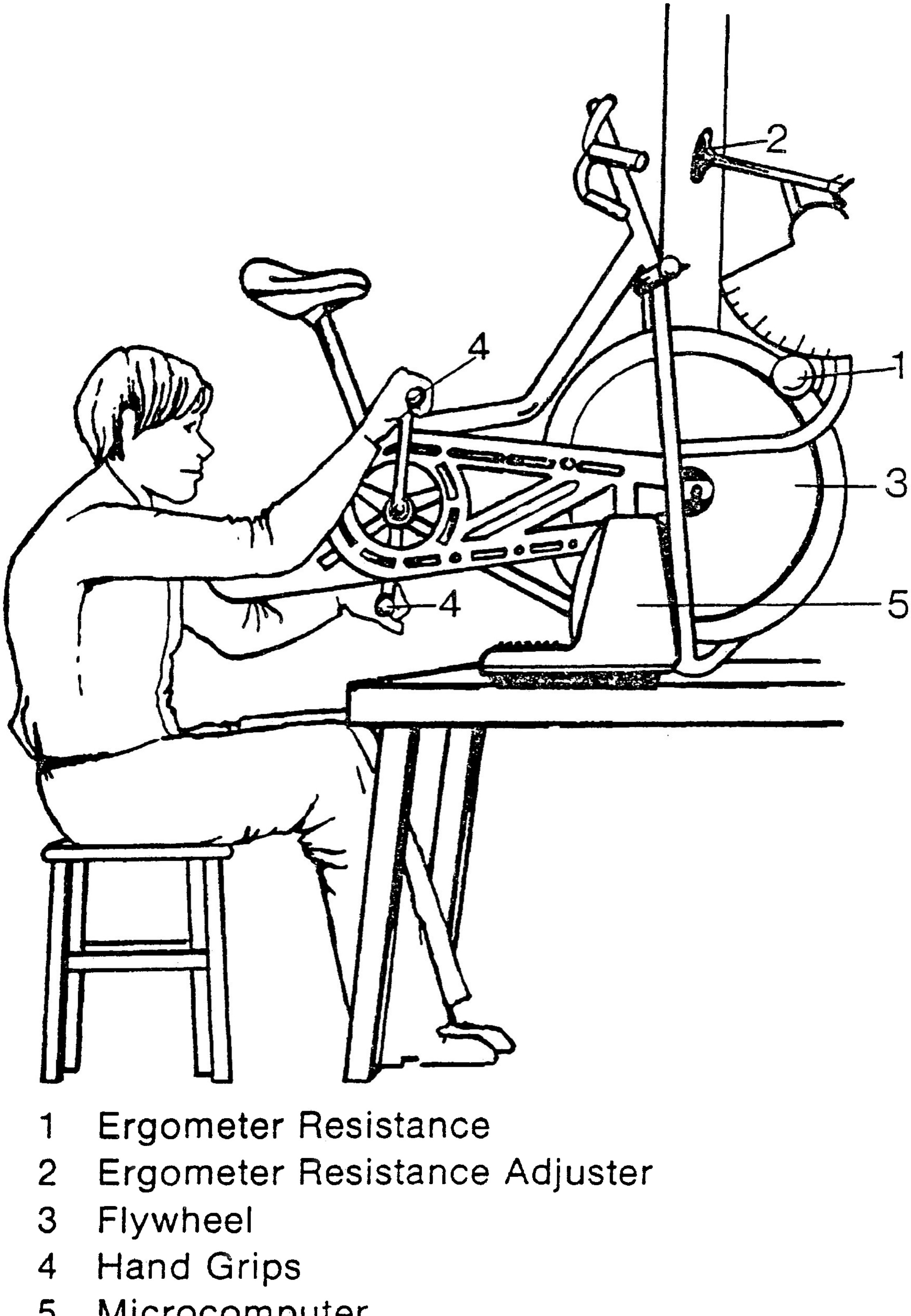
Figure 1

Figure 2



APPENDIX B

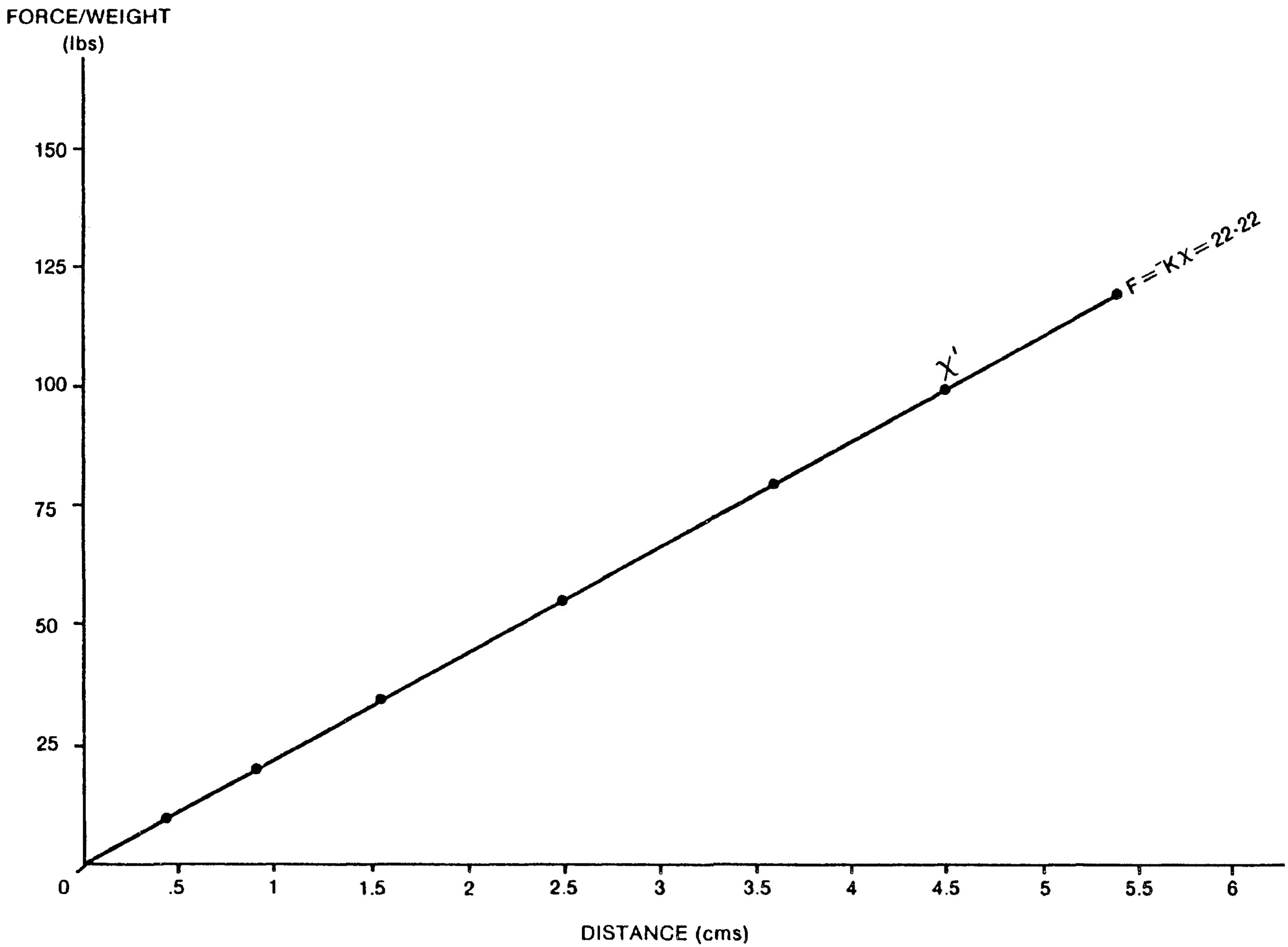
WINGATE ANAEROBIC ARM CRANKING TEST



1 Ergometer Resistance
2 Ergometer Resistance Adjuster
3 Flywheel
4 Hand Grips
5 Microcomputer

APPENDIX C

CALIBRATION CURVE OF PUNCHING DEVICE.



APPENDIX C

Calculation of Spring Constant (k)

Any two values on the straight line may be taken to find k. With k being a constant, each value for k will be the same. To calculate k, for example:

$$x' = 100 \text{ lbs vs } 4.5 \text{ cms}$$

$$\therefore x' = \frac{100 \text{ lbs}}{4.5 \text{ cms}}$$

$$= x' = 22.2$$

to convert this value into Newton Metres (N/M):

$$= \frac{22.22 \times 4.4822}{.01}$$

where: 1 lb = 4.4822 Newtons
1 cm = 0.01 Metres

$$\therefore \underline{k = 9959 \text{ N/M}}$$

This k value is then placed in the anaerobic power output value for the Arm Punching Test.

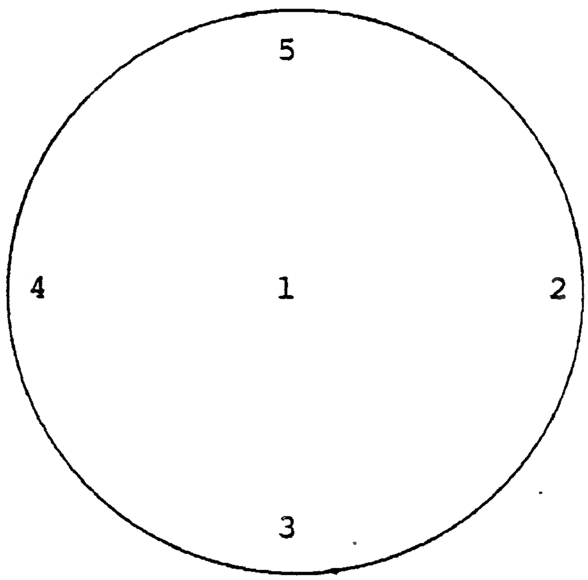
Hence:

$$\tfrac{1}{2} kx^2$$

where: k = spring constant
x = distance punched
t = time of punch

APPENDIX D

Calibration Points of Striking Plate



APPENDIX E

Punching Device Calibration (Tinius-Olsen)

Position	Offset	Input	Output	Error	% Error
1	Force Applied at Centre 0"	56	56.5	+0.5	+0.89
		108.2	110	+1.8	+1.66
		110	112.1	+2.1	+1.91
		157	157.2	+0.2	+0.13
		164.2	163.7	-0.5	-0.30
					Avg. +0.86%
2	Force Applied Along Load Cell Axis (up) 3.5" at 0^{o}	50.6	51.8	+1.2	+2.37
		103.4	105.1	+1.7	+1.64
		130.7	132.1	+1.4	+1.07
		141.8	144.5	+2.7	+1.90
		183.6	186	+2.4	+1.31
					Avg. +1.66%
3	Force Applied Across Load Cell Axis (right) 3.5" at 90^{o}	48.4	47.1	-1.3	-2.69
		50.6	50.9	+0.3	+0.59
		99	96	-3.0	-3.03
		140.2	140.4	+0.2	+0.14
		180.7	181.4	+0.7	+0.39
					Avg. -0.92%
4	Force Applied Along Load Cell Axis (down) 3.5" at 0^{o}	50.6	51.2	+0.6	+1.19
		103.4	106.1	+2.7	+2.61
		130.7	132.2	+1.5	+1.15
		141.8	144.7	+2.9	+2.05
		183.6	185.6	+2.0	+1.09
					Avg. +1.62%
5	Force Applied Across Load Cell Axis (left) 3.5" at 90^{o}	48.4	46.5	-1.9	-3.93
		50.6	50.7	+0.1	+0.20
		99	96.1	-2.9	-2.93
		140.2	140.6	+0.4	+0.29
		180.7	181.8	+1.1	+0.61
					Avg. -1.15%

* % Error Less Than 2% (1.66% Error Maximum)

APPENDIX F

Arm Punching Test Instructions

1. The first person drawn into group A will be tested first, the second person drawn into group A will be tested second, and the third person drawn into group A will be tested last.
2. Each individual test will take approximately 5 minutes.
3. Make sure you are completely warmed up and ready to give a maximal all-out punching effort.
4. For the test, you will strike the target with alternate straight right and left punches at a set distance from the target.
5. Each fist must return to chin level next to the shoulder after each punch.
6. One or both feet must not leave the floor or go out of the marked square around the feet.
7. A maximum of 10 warm-up punches will be used.
8. The length of the test will not be disclosed.

APPENDIX G

Wingate Anaerobic Arm Cranking Test Instructions

1. The first person drawn into group B will be tested first, the second person drawn into group B will be tested second.
2. Each individual test will take approximately 5 minutes.
3. In the test, you are asked to arm-crank all-out with both arms.
4. You must not leave the seated position.
5. A warm-up of 2 minutes will be given.
6. The length of the test will not be discovered.

APPENDIX H

Wingate Anaerobic Arm Cranking Test - Final Reliability Data Table

Subjects	5 (Revs)	10 (Revs)	15 (Revs)	20 (Revs)	25 (Revs)	30 (Revs)	(Watts) Final Total
89 kg) 1 Test (1)	9	17	25	32	39	44	457.25 Watts/Min
1 Test (2)	10	19	28	36	42	47	488.43 Watts/Min
70 kg) 2 Test (1)	10	21	29	35	41	46	378.82 Watts/Min
2 Test (2)	9	19	25	31	37	42	345.88 Watts/Min
75 kg) 3 Test (1)	10	18	26	32	38	44	388.24 Watts/Min
3 Test (2)	10	18	26	32	38	43	379.41 Watts/Min
80 kg) 4 Test (1)	8	17	23	28	33	38	357.65 Watts/Min
4 Test (2)	8	17	24	30	35	39	367.06 Watts/Min
92 kg) 5 Test (1)	10	21	29	37	42	46	496.08 Watts/Min
5 Test (2)	9	19	27	35	40	44	474.51 Watts/Min

Correlation Coefficient of r = 0.92

APPENDIX I

Table 7

Arm Punching Test - Final Reliability Data Table

Subjects	5 Second Anaerobic Power Output (Watts)	10 Second Anaerobic Power Output (Watts)	15 Second Anaerobic Power Output (Watts)	Average Anaerobic Power Output (Watts)
1 Test (1) 1 Test (2)	363.18 341.51	282.93 262.37	151.89 174.80	266.00 259.56
2 Test (1) 2 Test (2)	249.98 207.08	242.90 259.32	165.13 183.94	219.37 216.78
3 Test (1) 3 Test (2)	202.31 234.65	267.56 245.76	171.57 149.03	213.81 209.81
4 Test (1) 4 Test (2)	370.45 270.60	221.48 272.18	136.19 126.33	242.71 223.04
5 Test (1) 5 Test (2)	233.46 208.31	238.09 279.36	145.10 173.00	205.55 218.55

APPENDIX J

Arm Punching Test - Mean Reliability Data Table

Distance - (x) cms
Time - (t) secs

Subjects		5 Seconds (x)	5 Seconds (t)	10 Seconds (x)	10 Seconds (t)	15 Seconds (x)	15 Seconds (t)
1	Test 1	3.44	0.148	3.41	0.168	2.78	0.187
1	Test 2	3.13	0.130	2.71	0.146	2.96	0.177
1 Punches	Test 1	9		8		7	
1 Punches	Test 2	9		8		7	
2	Test 1	2.11	0.081	2.44	0.113	2.40	0.142
2	Test 2	2.02	0.091	2.75	0.117	2.46	0.138
2 Punches	Test 1	9		9		8	
2 Punches	Test 2	9		8		8	
3	Test 1	2.09	0.087	2.50	0.111	2.46	0.143
3	Test 2	2.34	0.093	2.68	0.117	2.46	0.147
3 Punches	Test 1	8		9		8	
3 Punches	Test 2	8		8		7	
4	Test 1	2.45	0.082	2.25	0.105	2.06	0.126
4	Test 2	2.44	0.100	2.77	0.133	2.15	0.151
4 Punches	Test 1	10		9		8	
4 Punches	Test 2	9		9			
5	Test 1	2.56	0.115	3.25	0.140	2.83	0.183
5	Test 2	2.53	0.111	3.06	0.138	2.75	0.154
5 Punches	Test 1	8		6		6	
5 Punches	Test 2	7		8		7	

APPENDIX K

Arm Punching Test - Mean Final Testing Data Table

Distance - (x) cms
Time - (t) secs

Subjects	5 Seconds (x)	(t)	10 Seconds (x)	(t)	15 Seconds (x)	(t)
1 Test 1	3.31	0.128	3.02	0.142	2.39	0.148
1 Punches Test 1	8		9		7	
2 Test 1	2.25	0.092	2.56	0.123	2.12	0.136
2 Punches Test 1	9		8		8	
3 Test 1	2.28	0.090	2.80	0.130	2.09	0.138
3 Punches Test 1	8		9		8	
4 Test 1	2.41	0.087	2.44	0.104	1.96	0.121
4 Punches Test 1	9		9		8	
5 Test 1	2.89	0.118	3.59	0.152	2.39	0.135
5 Punches Test 1	7		8		7	